EARTHQUAKE ENGINEERING RESEARCH PROGRAM

Behavior of Liquefying Soils & Remedial Measures

Field Review Group

Tuesday, June 19, 2001

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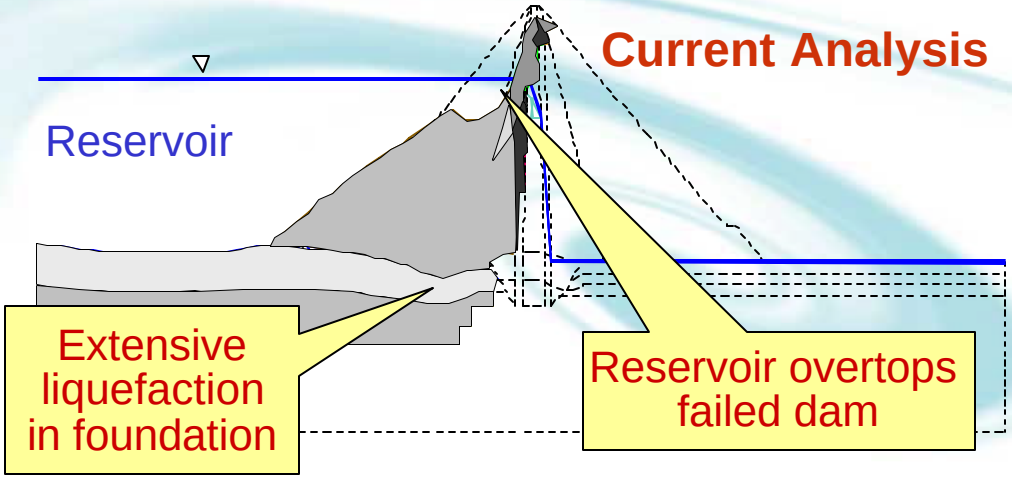
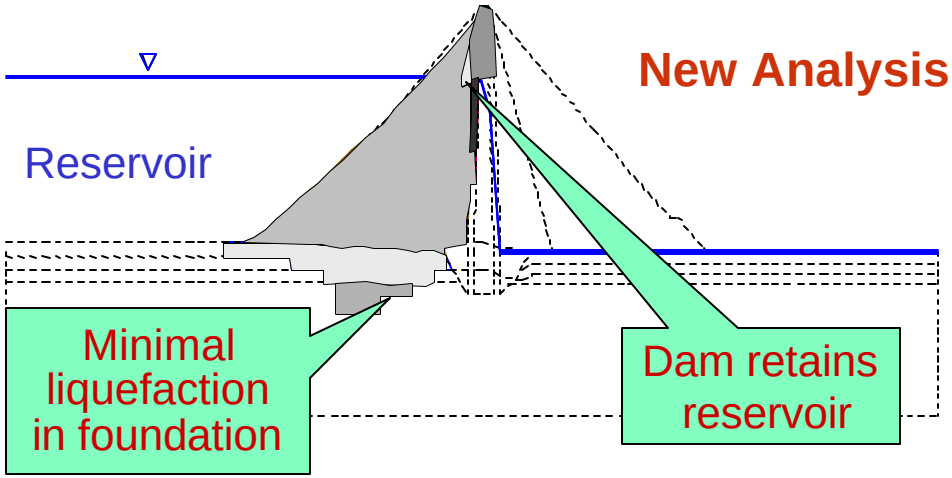


- **Current analysis indicates dam failure**
- **Remediation costs $35 Million (Mormon Island Dam)**



- **New analysis indicates minor damage**
- **Substantial savings in remediation costs, tens of millions**

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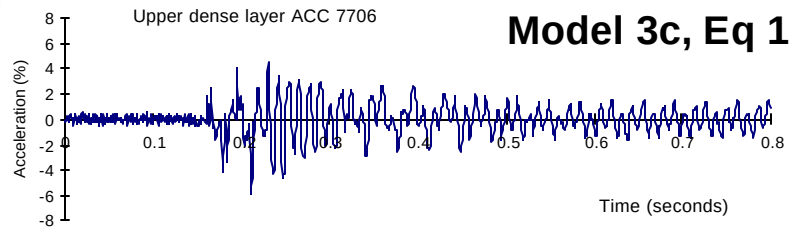
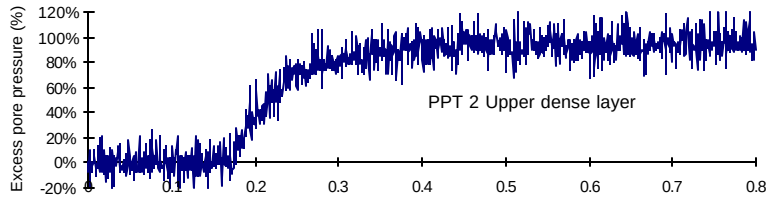
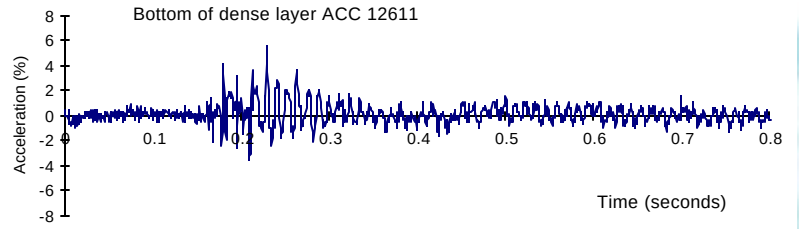
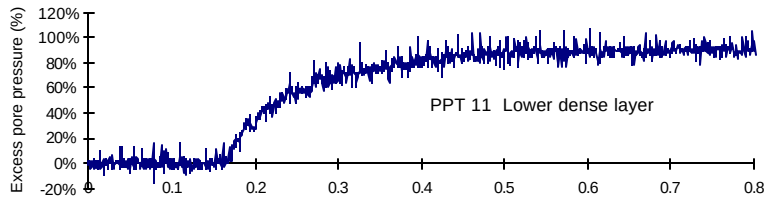
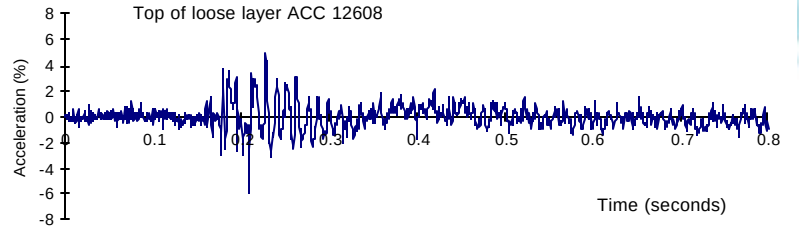
Model 3c, Eq 1

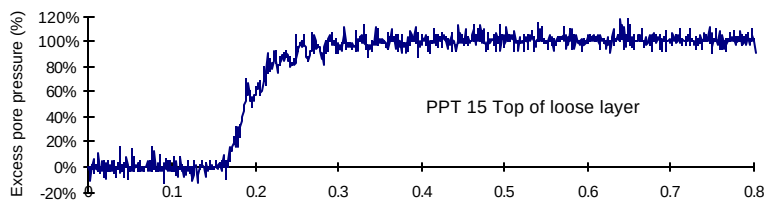


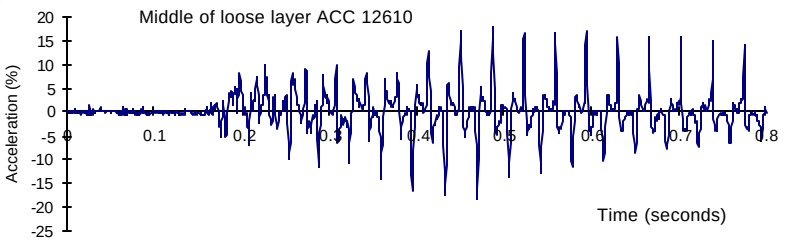


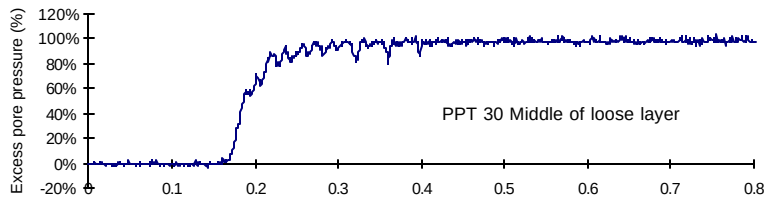


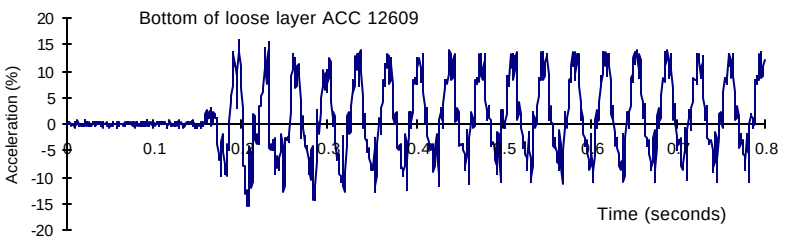


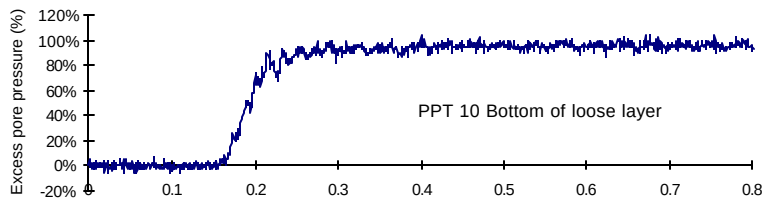












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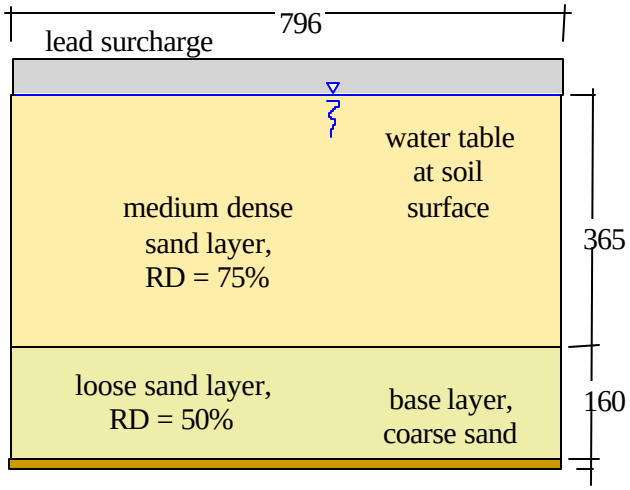
Excess pore pressures in Model 4d, earthquake 2

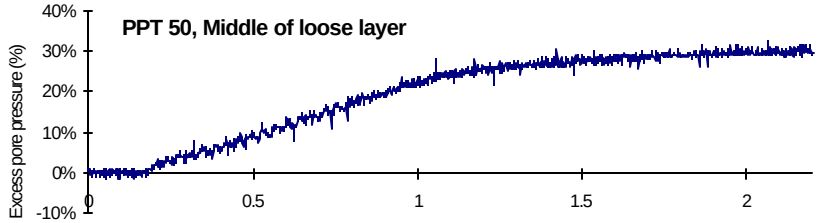
Middle depth specimen

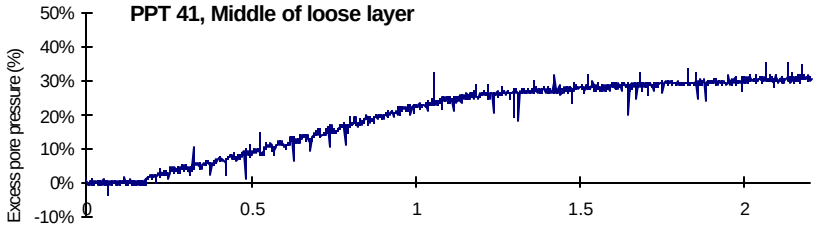
s_v' = 4.7 tsf

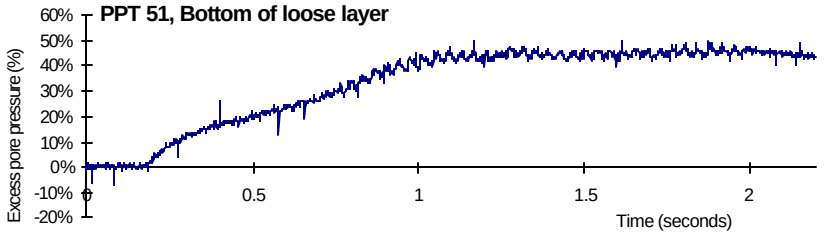
(in the middle of the loose layer)

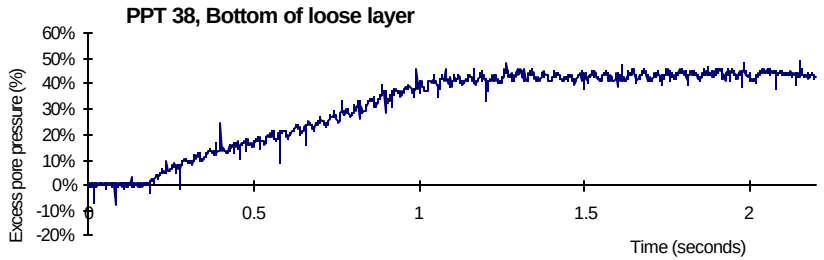
Shows good repeatability along the length of the model

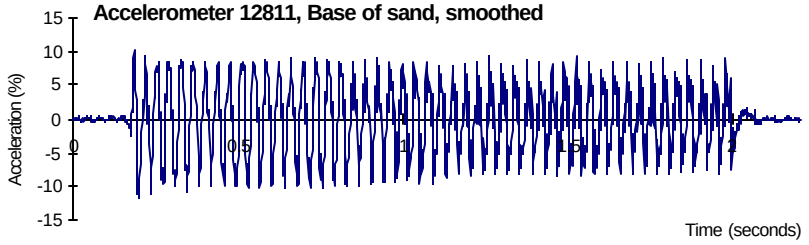












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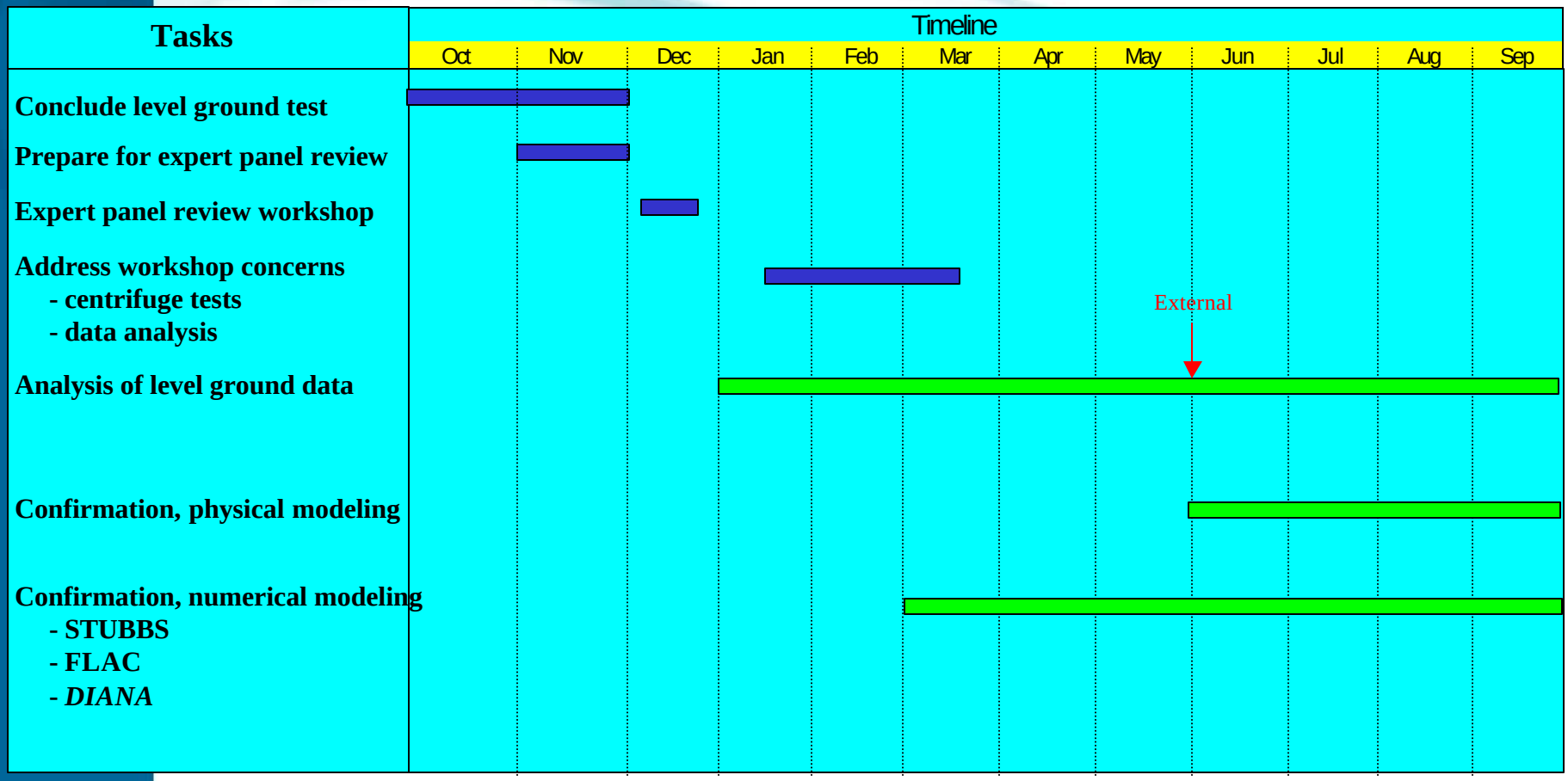
Plan for FY01



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Model series	Models in series	Effective overburden stress in loose layer	Depth of equivalent field deposit (approx)	Depth of specimen	Notes (All models used Nevada sand and were tested at 50g unless indicated)
2	a, b, c, d, e, f	1 tsf	15 m	300 mm	
3	a, b, c, d, e	2 tsf	26 m	525 mm	
4	a, b, c, d	3 – 5 tsf	26 – 40 m	525 mm	Lowered water table or lead surcharge
	e, f, g, h, I, j	3.9 – 9.7 tsf	30 – 60 m	525 mm	Light surcharge and change in g level
	k	1.9 – 4.8 tsf	25 – 39 m	525 mm	Change in g level
5	a, b, c, d, e	7 – 10 tsf	54 – 63 m	525 mm	Lead surcharge

Results of Expert Panel Review

BEHAVIOR OF LIQUEFYING SOILS

Technical Specialists Meeting
12 – 13 December 2000

REPORT OF MEETING

Attendees

Background

Synopsis of Meeting

Technical Specialists Comments

ERDC Research Team Plan of Action

Conclusion

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Results of Expert Panel Review

BEHAVIOR OF LIQUEFYING SOILS

Technical Specialists Meeting
12 – 13 December 2000

REPORT OF MEETING

Attendees:

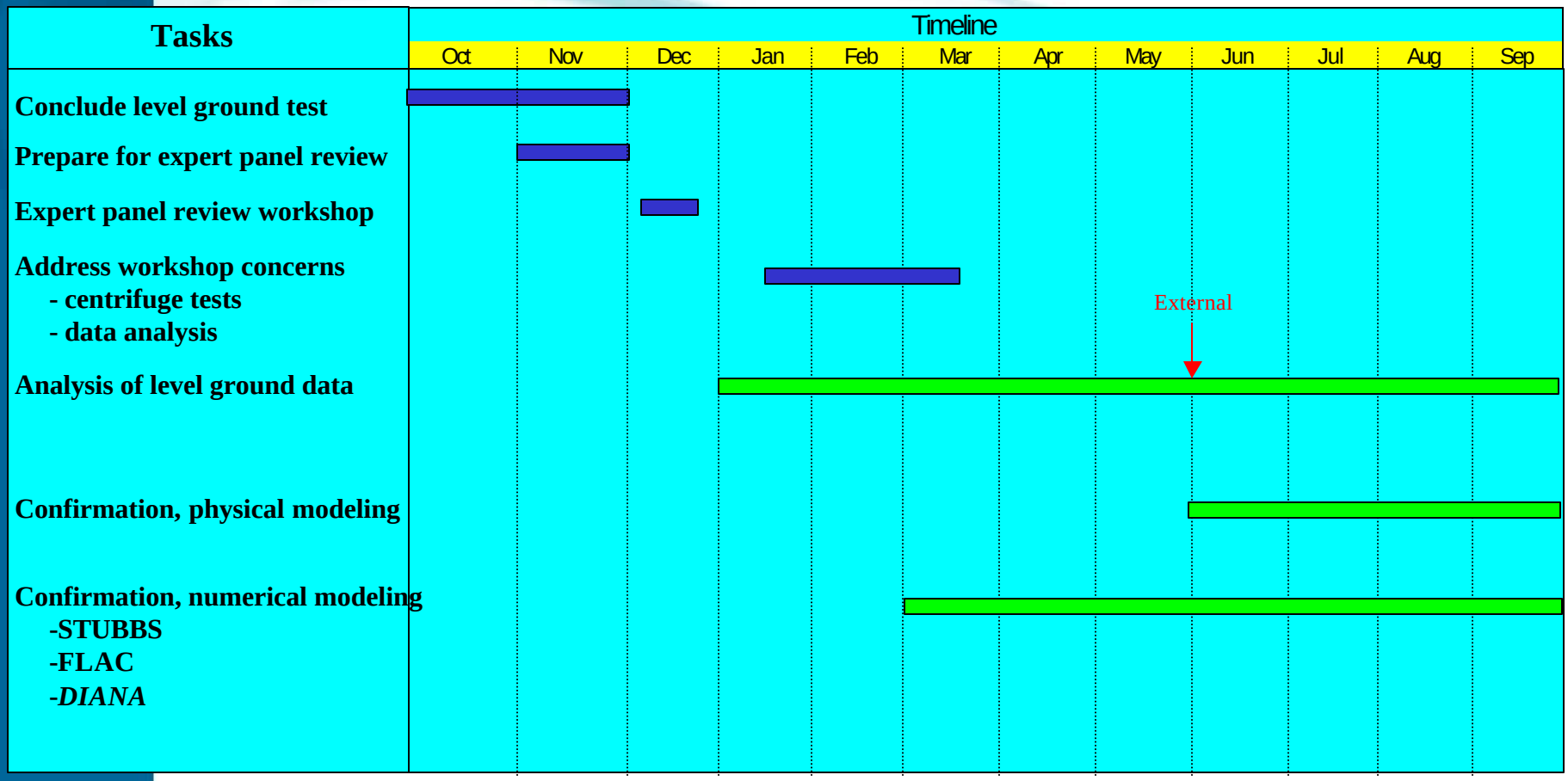
ERDC Research Team

Dr M.K. Sharp
Dr R.S. Steedman
Dr J.F. Peters
Dr M.E. Hynes
Ms W. Vanadit-Ellis
Dr M.J. O'Connor
Mr R. Ledbetter

Invited Technical Specialists

Dr W.F. Marcuson
Professor R. Dobry
Professor J.K. Mitchell
Dr G. Castro
Professor R. Seed
Professor P.M. Byrne
Professor S. Kramer
Professor R. Boulanger
Dr D.R. Gillette
(I. Idriss and W.L. Finn)

Plan for FY01



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Addressing Workshop Concerns

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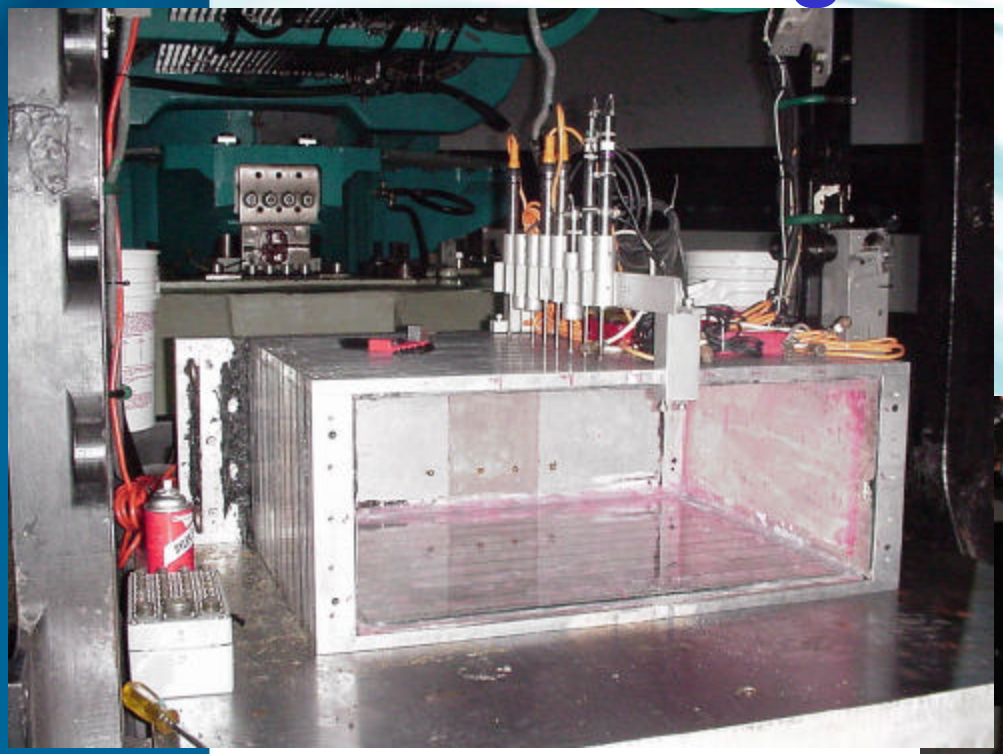
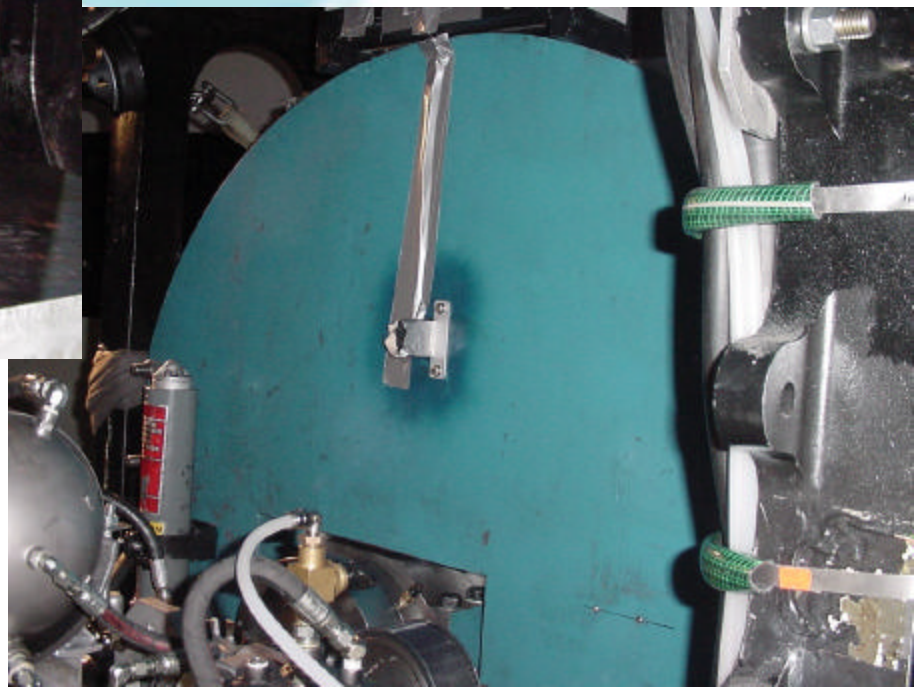
Addressing Workshop Concerns





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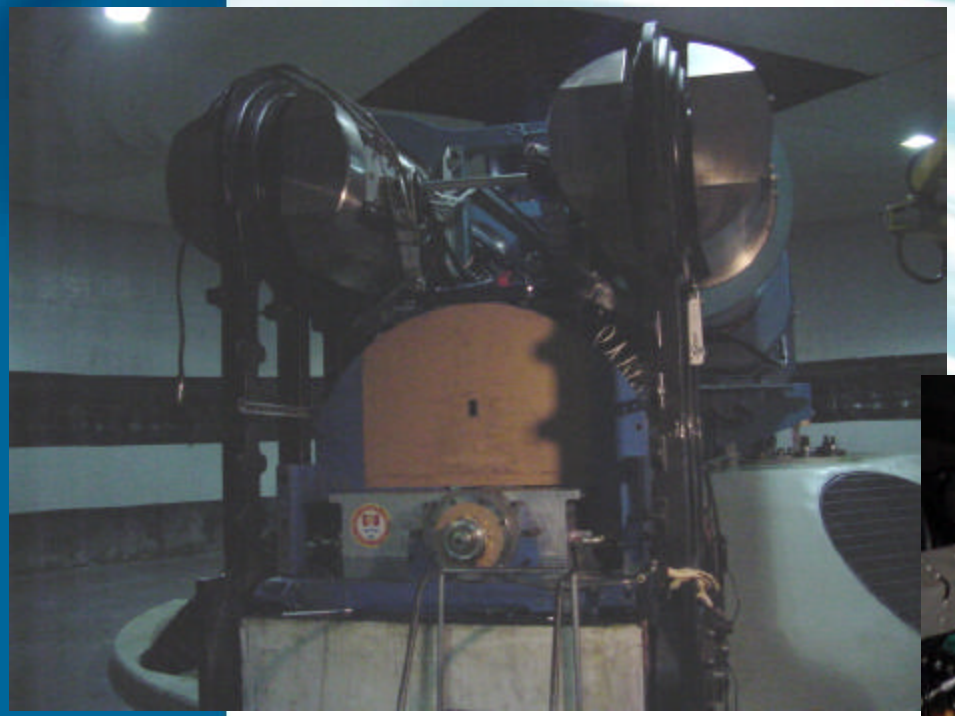
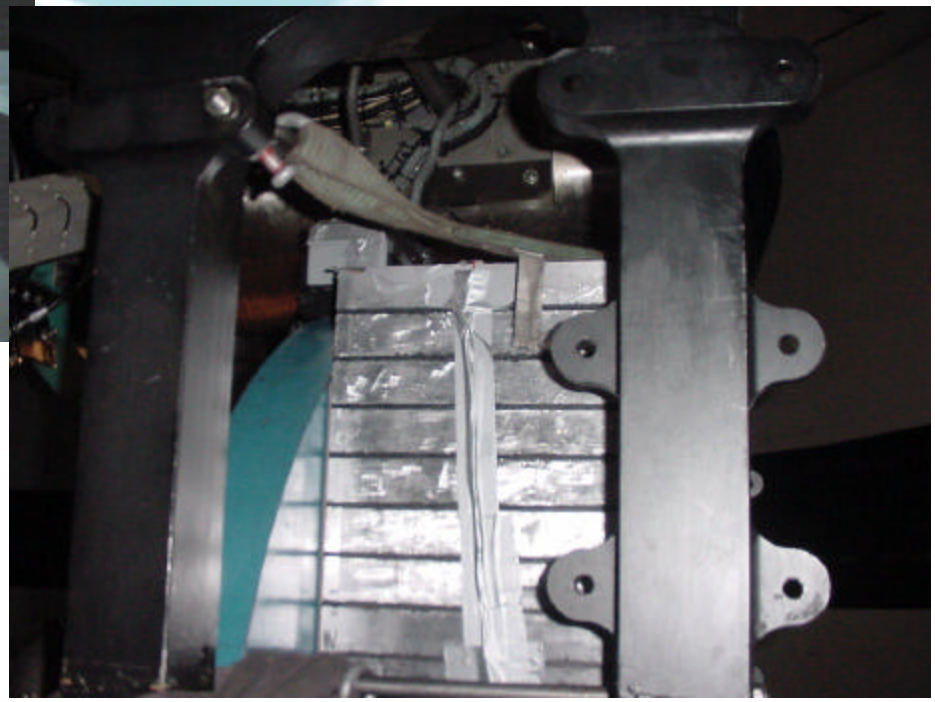
Addressing Workshop Concerns





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Addressing Workshop Concerns

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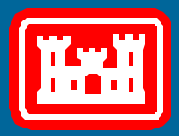
Additional ‘Check’ Tests

- Model with P/S wave hammer, total pressure cell, and acc’s on inside rings
- True model of the models to eliminate concerns about model size
- Clay layer between loose and dense layer



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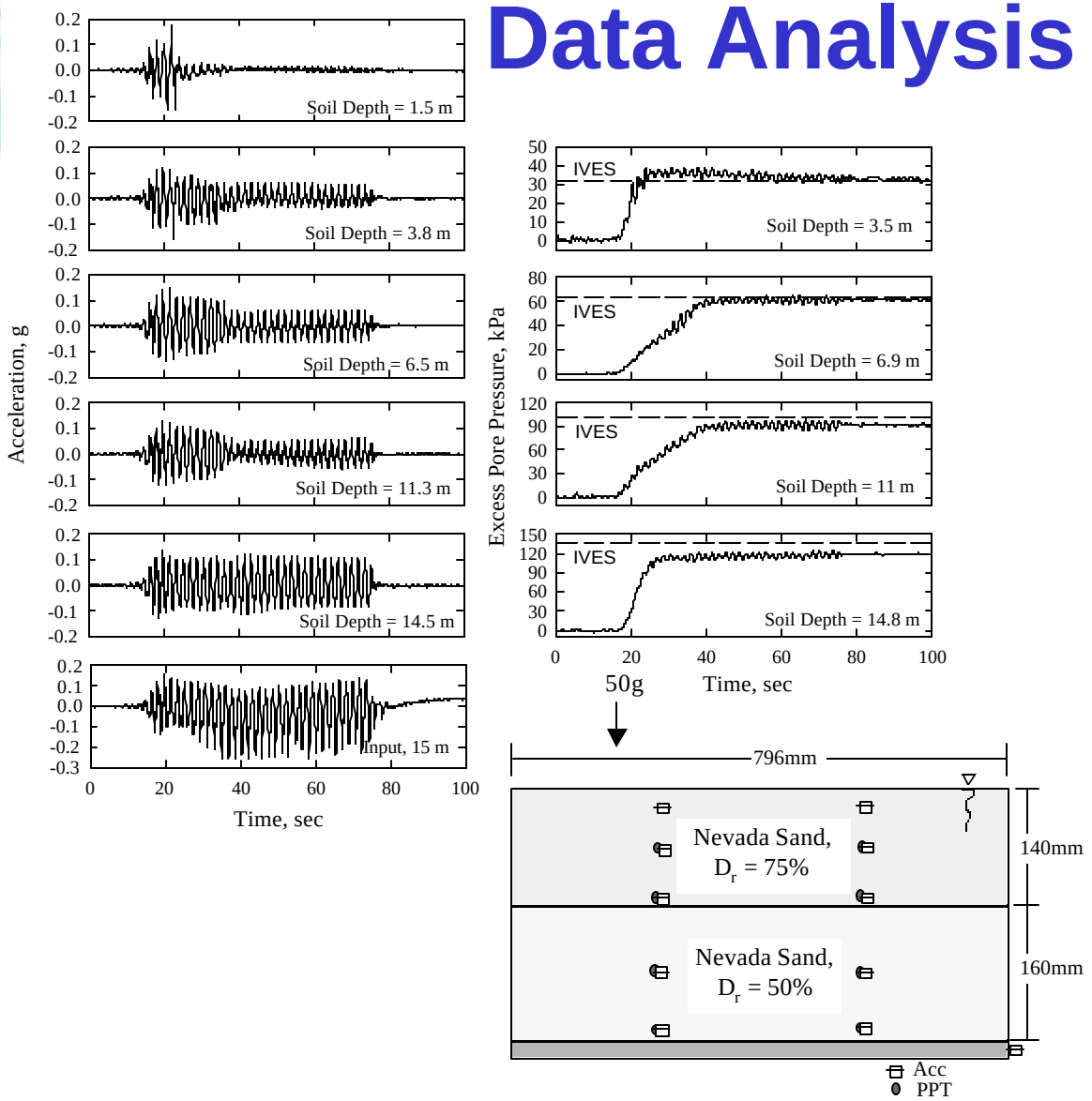
Data Analysis



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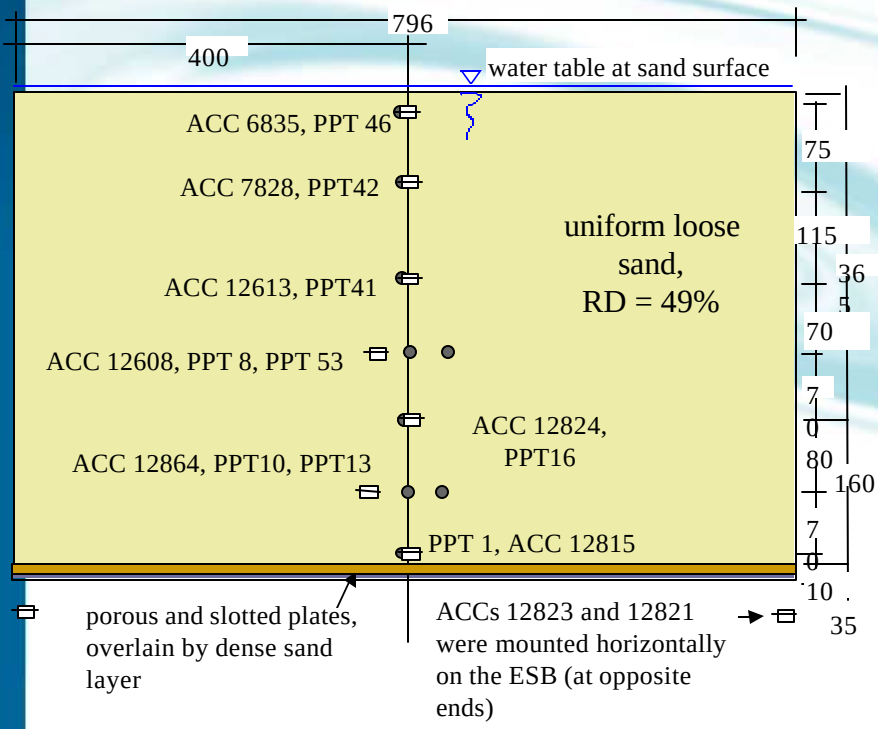
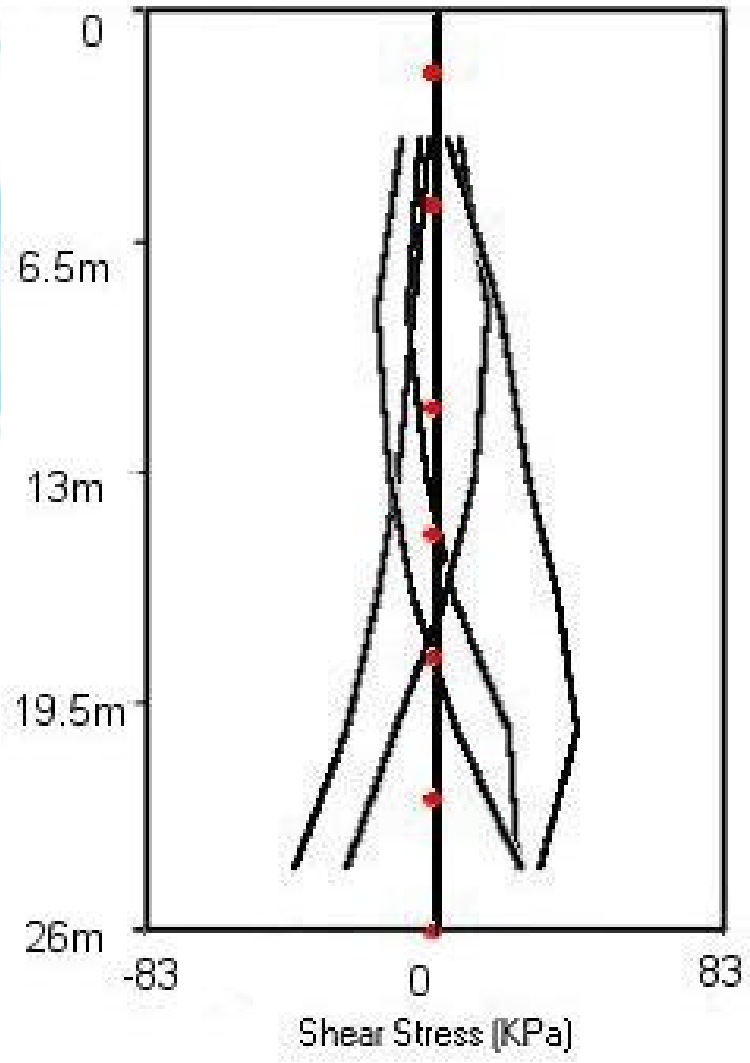
Data Analysis





Animation of shear stress at different depths

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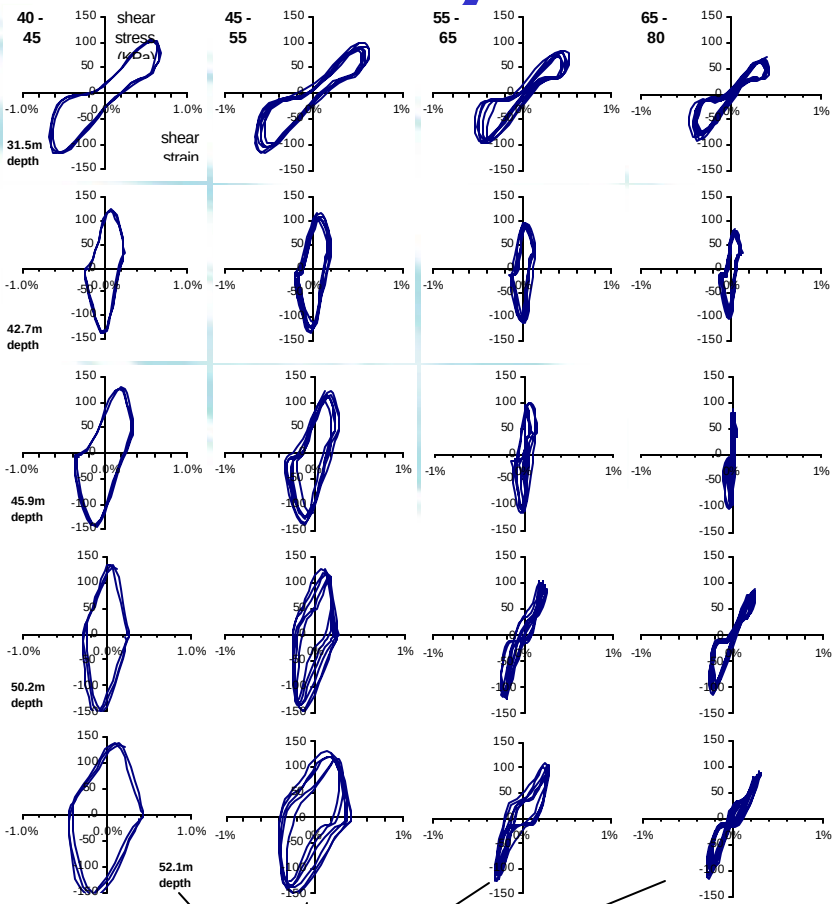
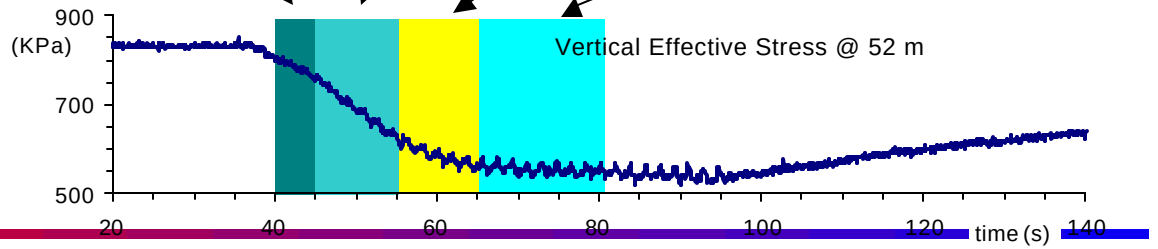
Data Analysis



Vertical effective stress at base of model



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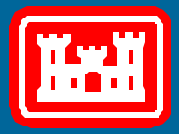
Additional FY01 Activities

- Independent verification through physical modeling by outside source (3 - 4 models)
- Numerical modeling with FLAC, DIANA, (STUBBS)
- SI analysis



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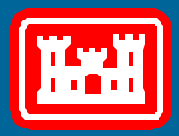
Technical Plan Overview
FY01- FY04

- FY01
  - Address comments from Dec 2000 review panel
  - Conclude level ground testing
  - Document results
- FY02
  - Finalize level ground testing & document
  - Plan & start sloping ground tests
- FY03
  - Conclude sloping ground tests
  - Analyze tests and document results
- FY04
  - Integrate level and sloping ground tests into a final recommended design procedure



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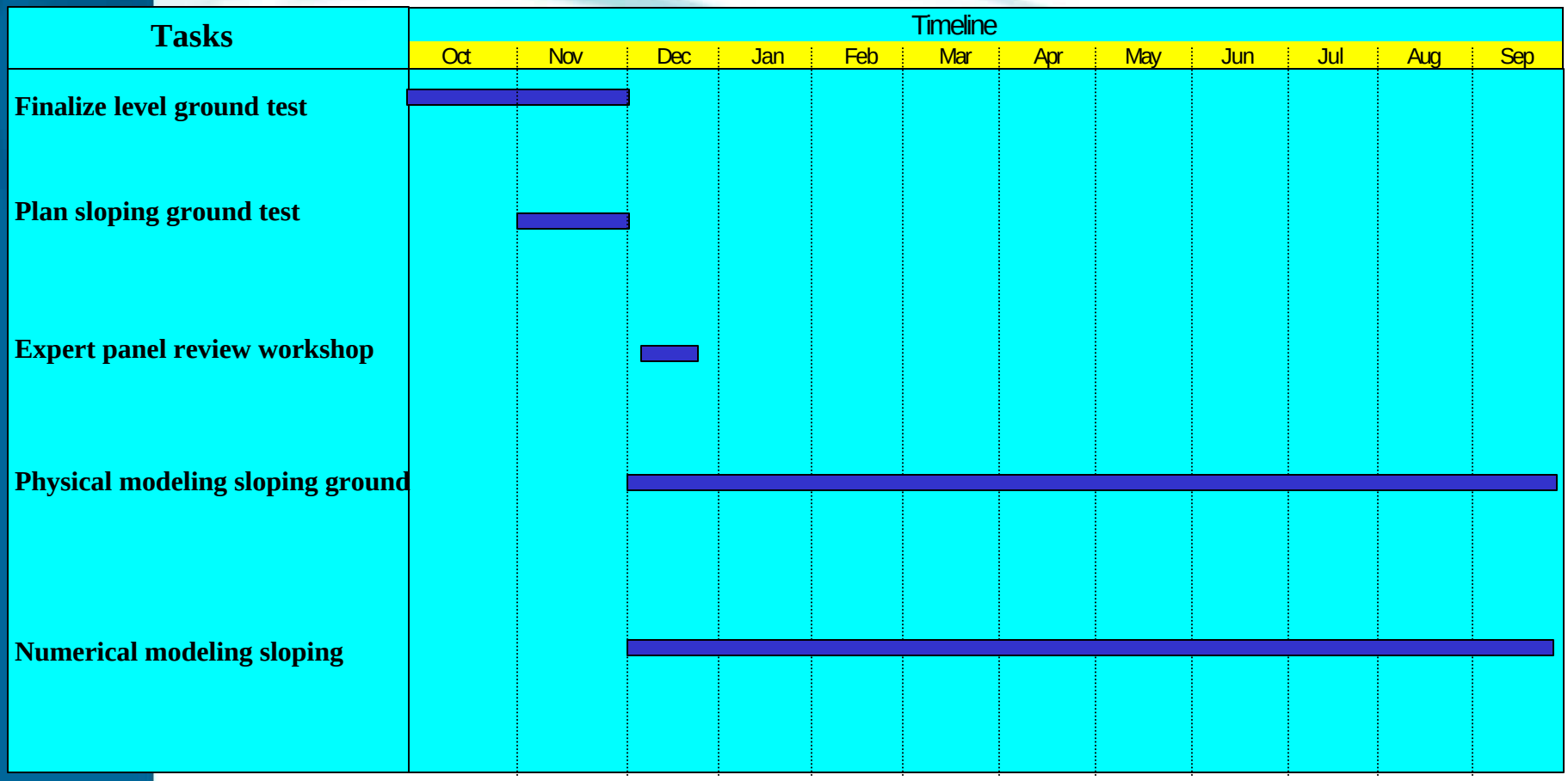
Plan for FY02



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Acceptance by Practice

Journal Articles

- Submit article to ASCE this July (planned)
- Submit article to ASCE NLT December 2001
- Submit to International Journal of Physical Modeling, 2001-2002

Conferences (Past)

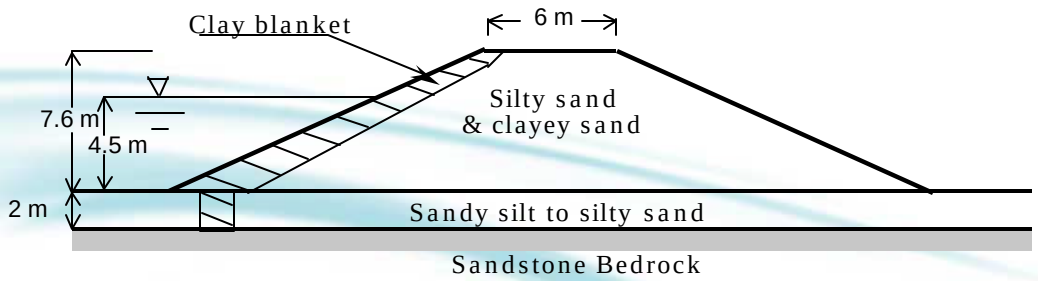
- GeoDenver 2000, ASCE, Proceedings
- 4th International Conference on Recent Advances…, 2001, Proceedings
- UJNR Workshops, 2000

Conferences (Future)

- ISSMGE, Turkey, 2001
- T2 Committee, Canada, 2002
- ECEE, UK, 2002

Workshop for Expert Panel Review

- Dec 2000
- Dec 2001



Failure due to Earthquake-Induced Liquefaction in Foundation:
Sheffield Dam during Santa Barbara Earthquake of 1925 (Seed 1970)

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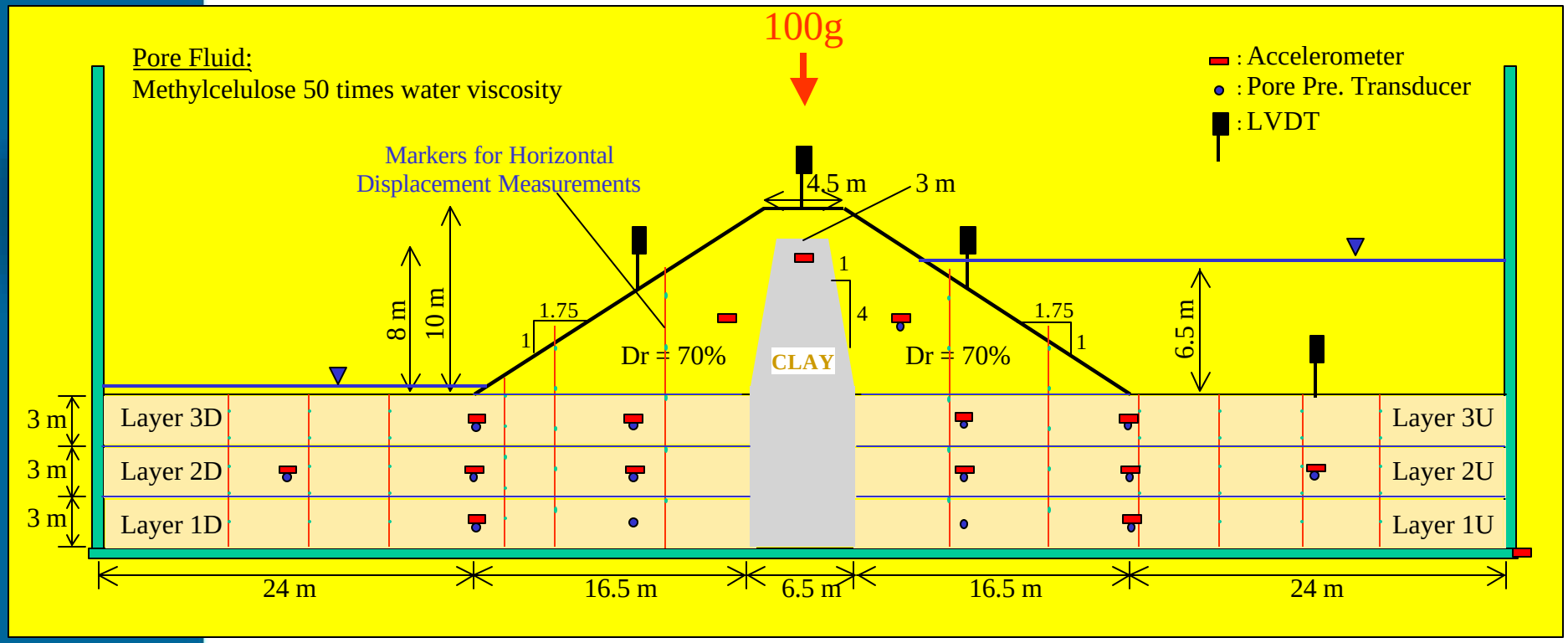

Tests:

SERIES 1	Vary ***depth*** of loose layer in foundation
SERIES 2	Vary ***thickness*** of loose layer in foundation
SERIES 3	Vary ***location*** of loose layer in foundation

Loose: Dr=35%,
Dense: Dr= 70%

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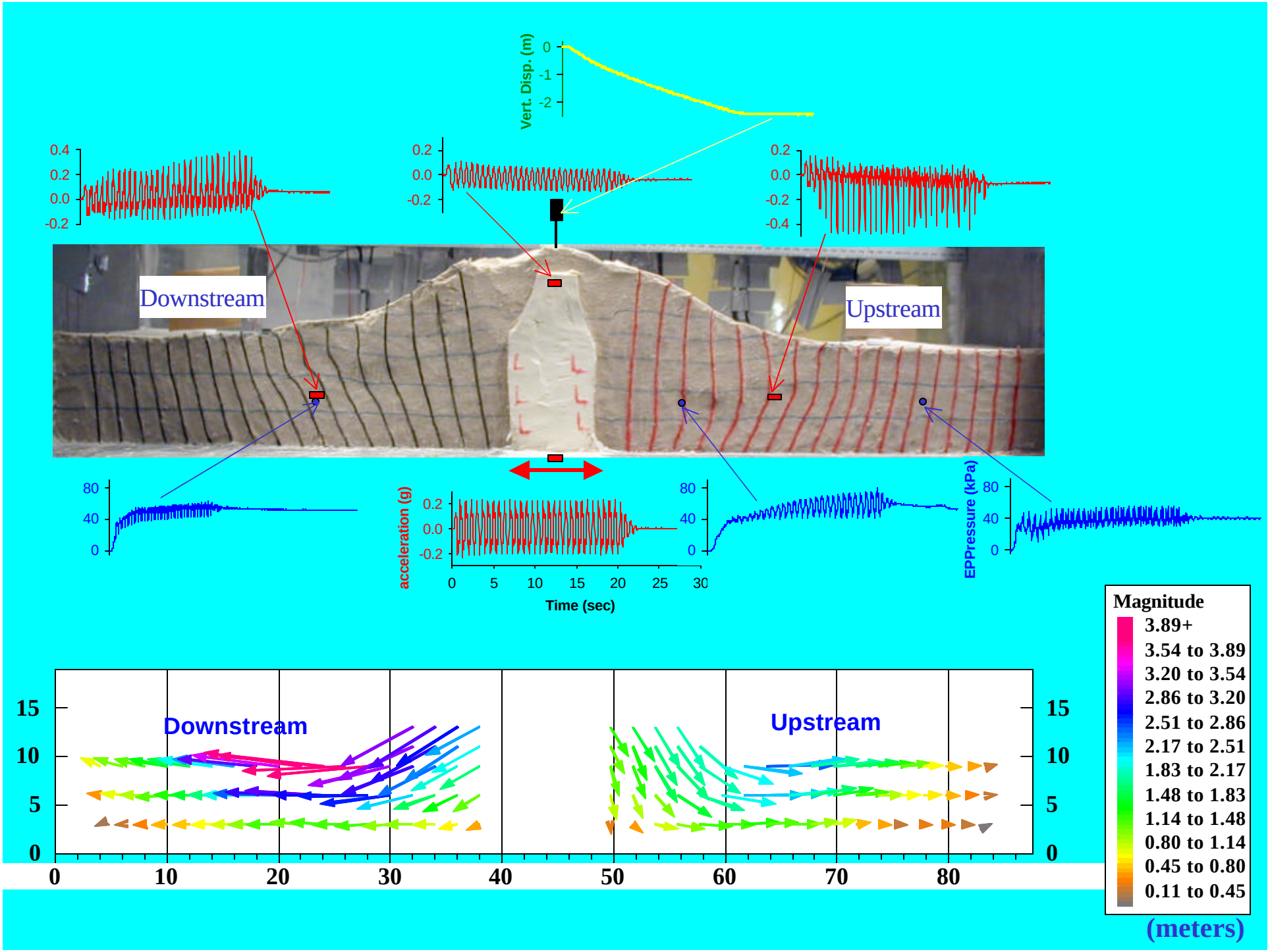
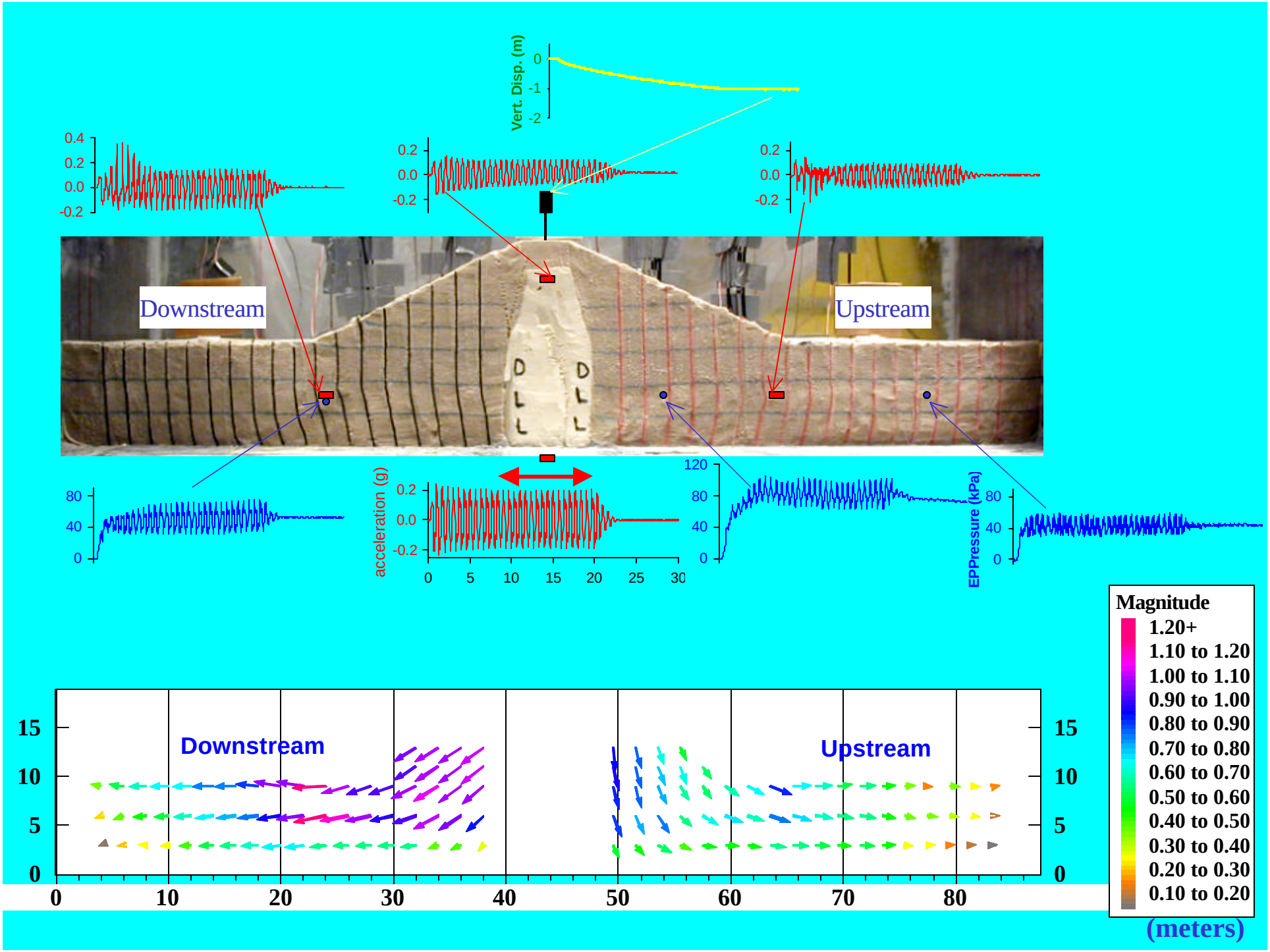
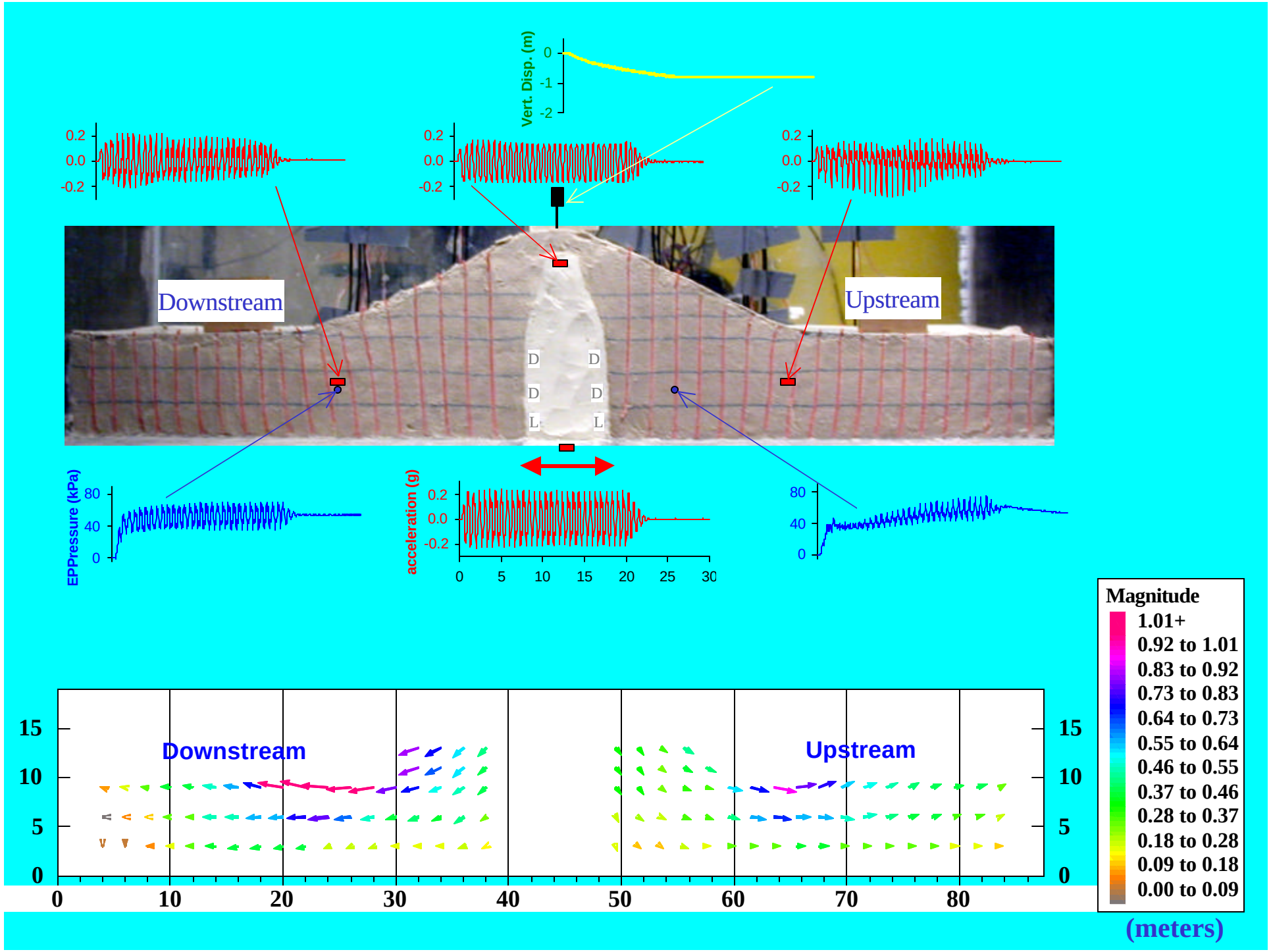
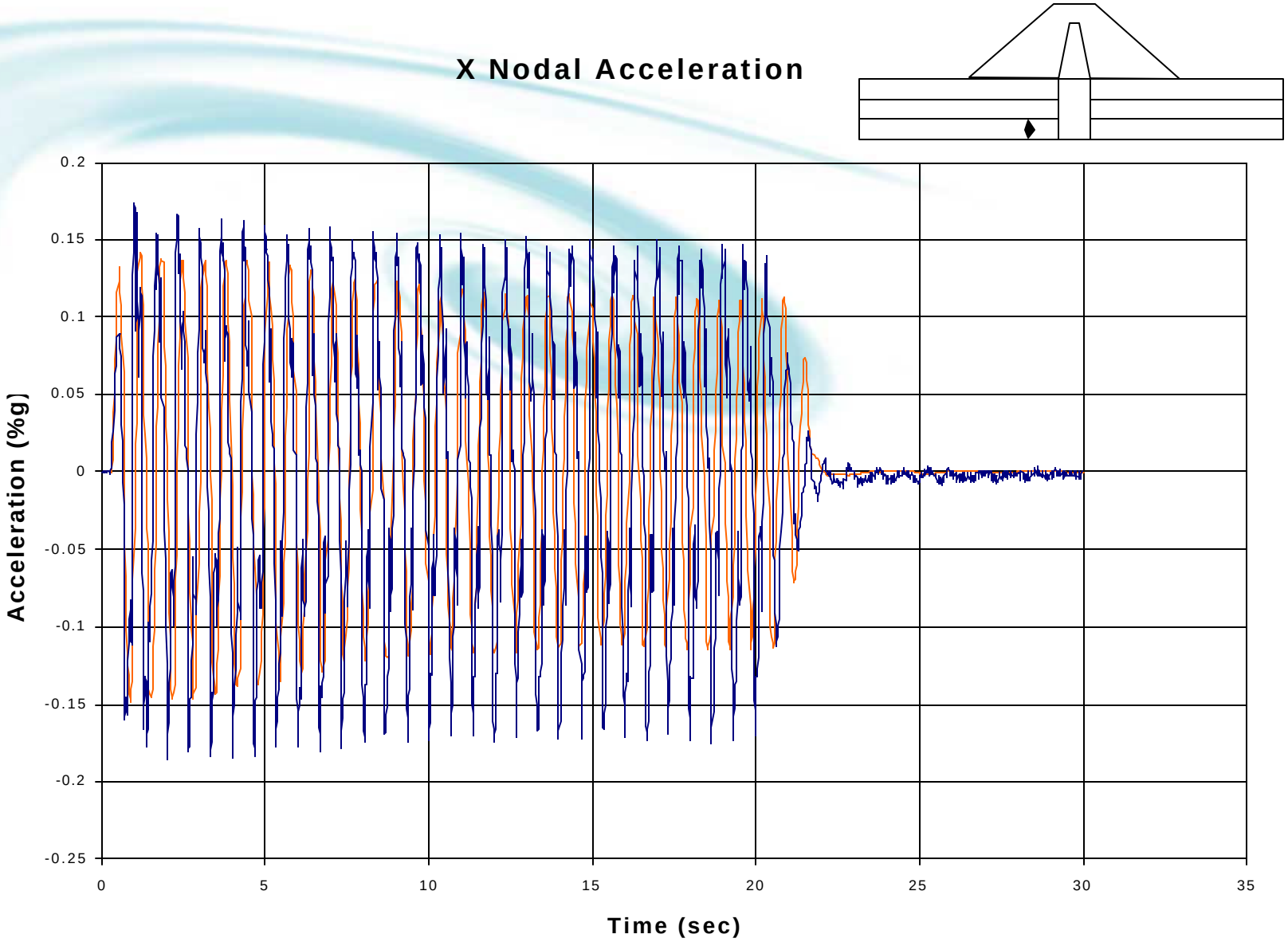

Vert. Disp. (m)
Downstream
Upstream
acceleration (g)
EPPressure (kPa)
Time (sec)
Magnitude
3.89+
3.54 to 3.89
3.20 to 3.54
2.86 to 3.20
2.51 to 2.86
2.17 to 2.51
1.83 to 2.17
1.48 to 1.83
1.14 to 1.48
0.80 to 1.14
0.45 to 0.80
0.11 to 0.45
(meters)


Vert. Disp. (m)
0
-1
-2
0.4
0.2
0.0
-0.2
0.2
0.0
-0.2
0.2
0.0
-0.2
Downstream
Upstream
D
L
L
D
L
L
80
40
0
acceleration (g)
0.2
0.0
-0.2
0
5
10
15
20
25
30
120
80
40
0
EPPressure (kPa)
80
40
0
Magnitude
1.20+
1.10 to 1.20
1.00 to 1.10
0.90 to 1.00
0.80 to 0.90
0.70 to 0.80
0.60 to 0.70
0.50 to 0.60
0.40 to 0.50
0.30 to 0.40
0.20 to 0.30
0.10 to 0.20
Downstream
Upstream
15
10
5
0
0
10
20
30
40
50
60
70
80
(meters)


Vert. Disp. (m)
0
-1
-2
0.2
0.0
-0.2
Downstream
Upstream
D
D
D
D
L
L
EPPressure (kPa)
80
40
0
acceleration (g)
0.2
0.0
-0.2
0
5
10
15
20
25
30
Downstream
Upstream
15
10
5
0
0
10
20
30
40
50
60
70
80
Magnitude
1.01+
0.92 to 1.01
0.83 to 0.92
0.73 to 0.83
0.64 to 0.73
0.55 to 0.64
0.46 to 0.55
0.37 to 0.46
0.28 to 0.37
0.18 to 0.28
0.09 to 0.18
0.00 to 0.09
(meters)



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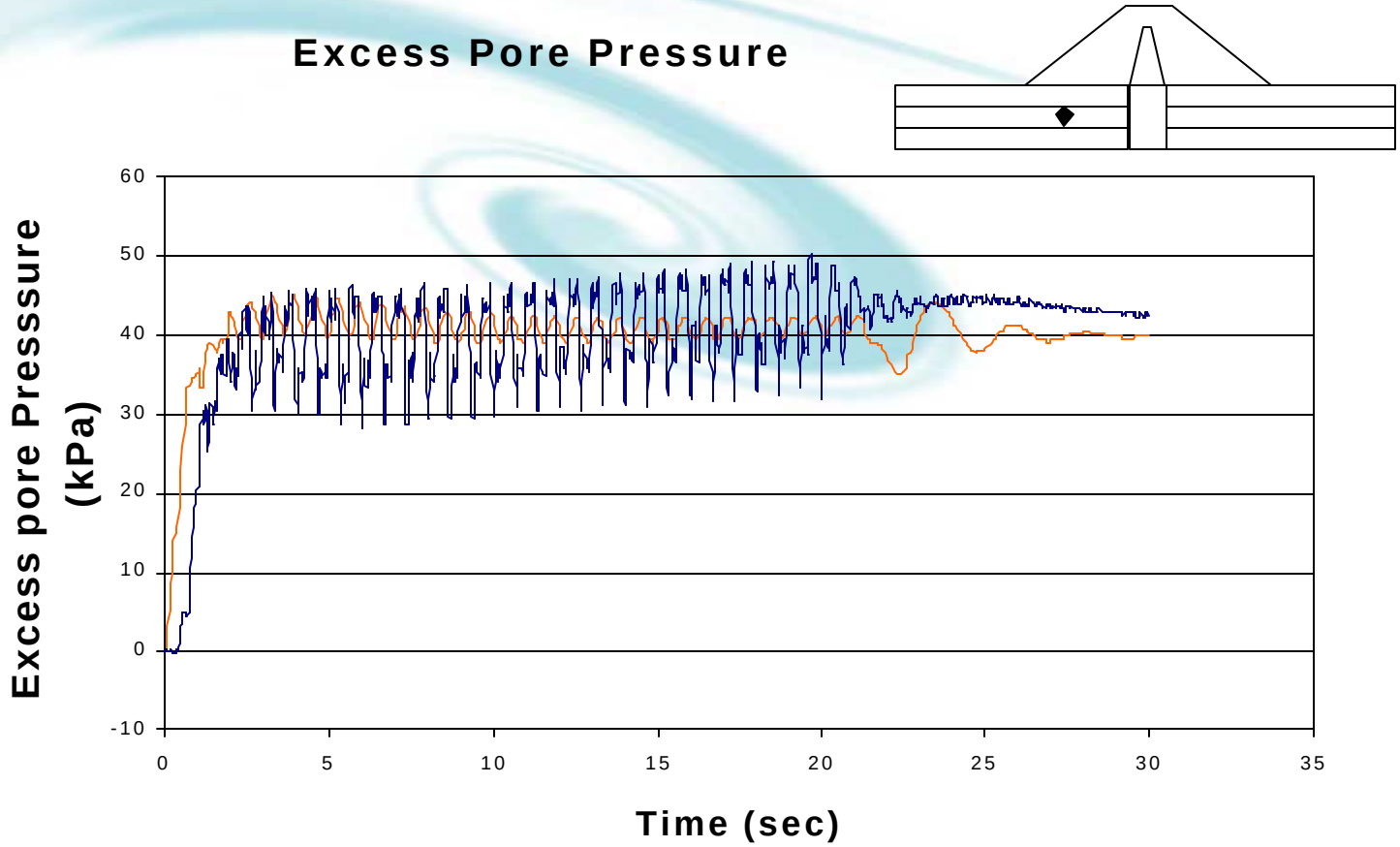

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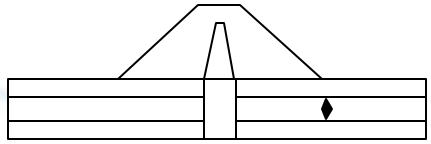

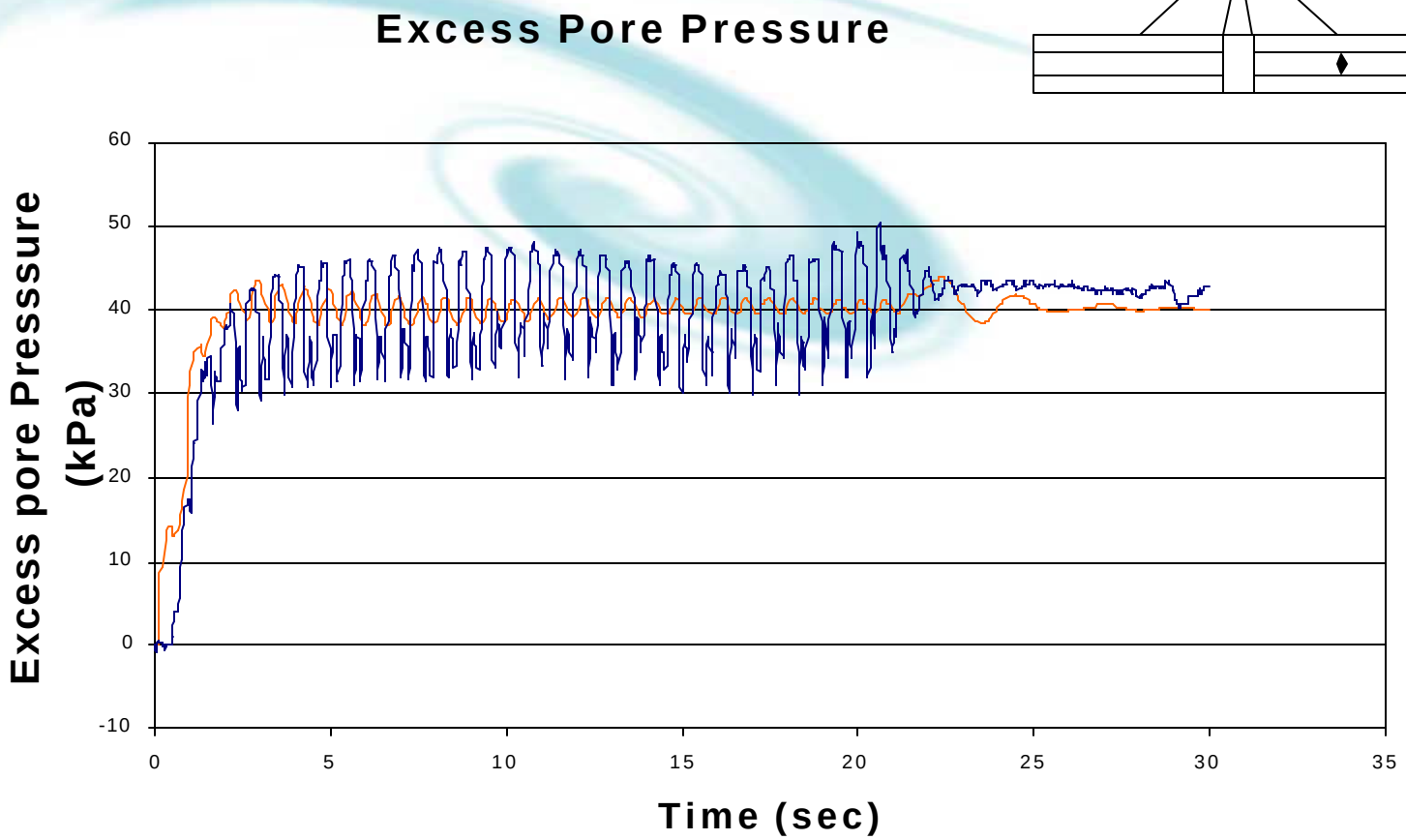

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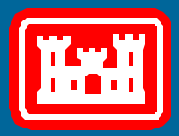

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